```
        function v52()

C Function produces the V.52 bit pattern called for in the digital FM
C interference measurement methodology.  Each time this function is
C called, it produces one bit of the V.52 pattern.

        integer v52          ! The returned V.52 bit.
        integer register     ! The shift register that holds the current
                             ! state of the LSFR.

        data register/511/   ! The initial state of the shift register.
        save register        ! Saving the shift register between calls.

C Returning the value in the LSB of the shift register.
        v52=and(register,1)

C Performing the EXOR and feedback function.
        if(and(register,17) .eq. 1 .or. and(register,17) .eq. 16) then
          register=register+512
        end if

C Shifting the LSFR by one bit.
        register=rshft(register,1)
        end
```

The data from the procedure above is binary, and can be used to drive binary data systems directly. Since many modulations utilize four level symbols, the binary symbols from the V.52 sequence must be pared up into 4-level symbols. This can be done with this procedure:

```
        function v52_symbol()

C Function produces a di-bit symbol based on the V.52 sequence and
C the Layer 1 translation table.


        integer v52               ! External V.52 function.
        integer bit_1,bit_0       ! The two bits of the di-bit pair.
        integer v52_symbol        ! Four level V.52 symbol.
        integer table(0:1,0:1)    ! Translation table to map bits into 4-
                                  ! level symbols.

C Setting up the translation table.
        data table/+3,-3,+1,-1/

C Making the V.52 draws and translating them to a 4-level symbol level
C with the translation table.
        bit_1=v52()
        bit_0=v52()
        v52_symbol=table(bit_1,bit_0)
        end
```

6.7 Delay Spread Methodology and Susceptibility

A method of quantifying modulation performance in simulcast and multipath environments is desired. Hess describes such a technique [4], pp. 240-246. Hess calls the model the "multipath spread model." The model is based on the observation that for signal delays that are small with respect to the symbol time, the bit error rate (BER) observed is a function of RMS value of the time delays of the various signals weighted by their respective power levels. This reduces the entire range of multipath possibilities to a single number. The multipath spread for N signals is given by:

$$T_m = 2\sqrt{\frac{\sum_{i=1}^{N} P_i d_i^2}{\sum_{i=1}^{N} P_i} - \frac{\left[\sum_{i=1}^{N} P_i d_i\right]^2}{\left[\sum_{i=1}^{N} P_i\right]^2}}$$

[Eq. 56]

Since BER is proportional to T_m, any value of N can be represented as if it were due to two rays of equal signal strength, as shown here:

$$T_m\Big|_{i=2;\,P_1=P_2} \square |d_2|$$

[Eq. 57]

Hess describes a method where multipath spread and the total signal power required for a given BER criteria are plotted and used in a computer program to determine coverage. Figure 12 in Section 6.7.1 shows this graph for QPSK-c class modulations at 5% BER given a 12 dB noise figure receiver. The points above and to the left of the line on the graph represent points that will have 5% BER or less, and thus meet the 5% BER criterion. The points below or to the right of the line have greater than 5% BER and thus do not meet the 5% BER criterion.

A figure of merit for delay spread is the asymptote on the multipath spread axis, which is the point at which it becomes impossible to meet the BER criterion at any signal strength. This is easily measured by using high signal strength and increasing the delay between two signals until the criterion BER is met. The two signal paths are independently Rayleigh faded. The other figure of merit for a modulation is the signal strength required for a given BER at T_m=0 μS. Given these attributes, the delay performance of the candidate modulation is bounded. It should be noted that these parameters are the figures of merit for the modulation itself; practical implementations, e.g., simulcast infrastructures, may change these curves. Figure 13 in Section 6.7.1 below shows the BER verses T_m at high signal strength for both QPSK-c class modulations.

6.7.1 QPSK-c Class Delay Spread Performance (12.5 and 6.25 kHz) Digital Voice

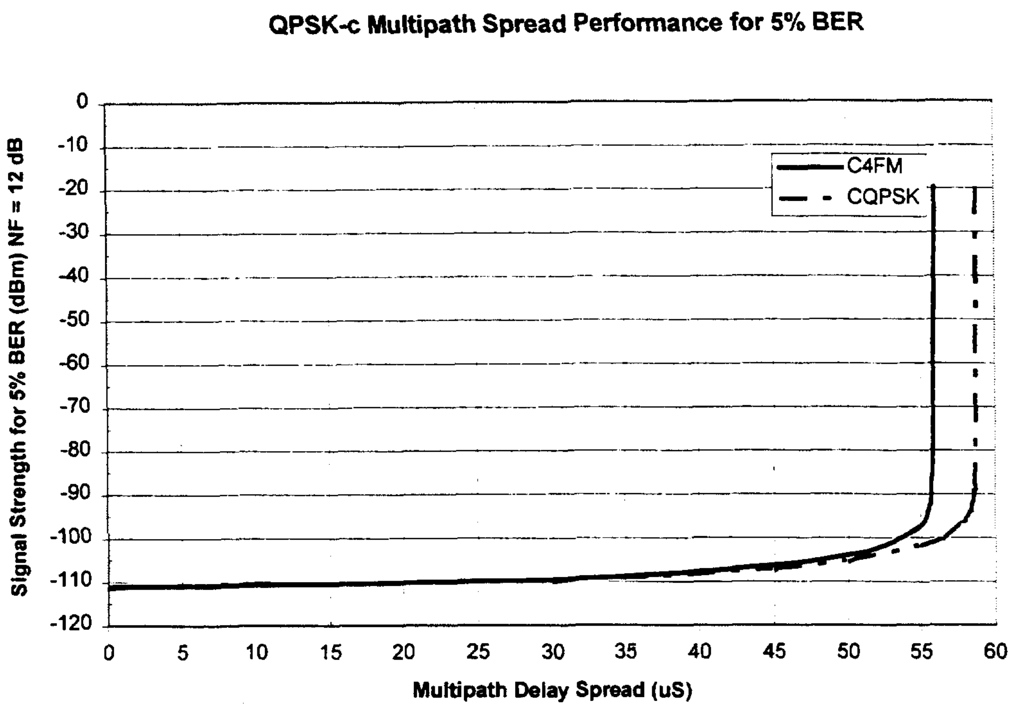

Figure 12. Multipath (Differential Phase) Spreads for APCO 25 Modulations

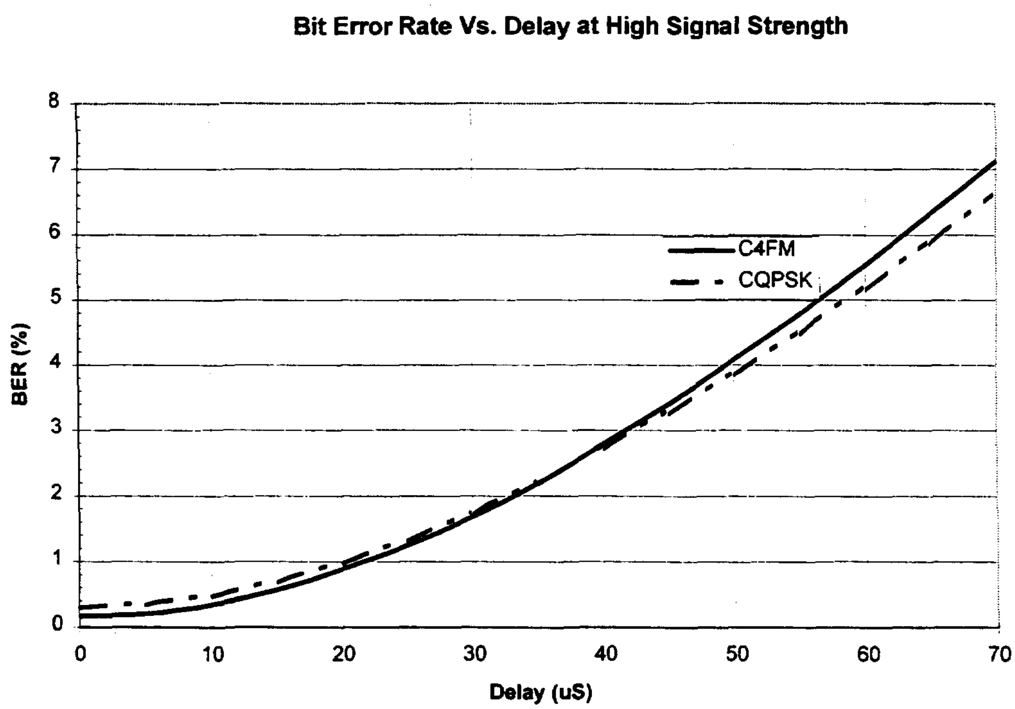

Figure 13. Simulcast Performance of APCO 25 Modulations

6.7.2 QPSK-c Type Delay Spread Performance (12.5 and 6.25 kHz) Digital Data

TBD

6.7.3 CVSD-XL Delay Spread Performance (25 kHz) Digital Voice

TBD

6.7.4 CVSD-XL NPSPAC Delay Spread Performance (12.5 kHz) Digital Voice

TBD

6.7.5 $\pi/4$ DQPSK (F-TDMA down link) Delay Spread Performance (12.5 kHz) Digital Voice

TBD

6.7.6 $\pi/4$ DQPSK (F-TDMA down link) Delay Spread Performance (12.5 kHz) Digital Data

TBD

6.7.7 EDACS® PRISM F-TDMA Delay Spread Performance (12.5 kHz) Digital Voice

TBD

6.7.8 EDACS® PRISM F-TDMA Delay Spread Performance (12.5 kHz) Digital Data

TBD

6.7.9 EDACS® Aegis Delay Spread Performance (25 kHz) Digital Voice

TBD

6.7.10 EDACS® Aegis Delay Spread Performance (25 kHz) Digital Data

TBD

6.7.11 EDACS® Aegis Delay Spread Performance (12.5 kHz) Digital Voice

TBD

6.7.12 EDACS® Aegis Delay Spread Performance (12.5 kHz) Digital Data

TBD

6.7.13 DIMRS Delay Spread Performance (25 kHz) Digital Voice

TBD

6.7.14 DIMRS Delay Spread Performance (25 kHz) Digital Data

TBD

6.7.15 TTIB/FFSR 16 QAM LM Delay Spread Performance (5 kHz) Digital Voice

TBD

6.7.16 TTIB/FFSR 16 QAM LM Delay Spread Performance (5 kHz) Digital Data

TBD

6.7.17 TTIB/FFSR 128 QAM LM Delay Spread Performance (5 kHz) Digital Data

TBD

6.7.18 RZ-SSB 16 QAM LM Delay Spread Performance (5 kHz) Digital Voice

TBD

6.7.19 RZ-SSB 16 QAM LM Delay Spread Performance (5 kHz) Digital Data

TBD

6.8 Conformance Measurements

6.8.1 Local Mean

In cases where dynamic range may be limited, the local mean should be captured and compared against the local median. The upper and lower deciles and standard deviation of the samples should also be measured. Characterization of these parameters is not required at each test sample location. Subsampling to perform these measurements should be done with a receiver calibrated at its antenna port. The use of a mean power value generally requires a detection system possessing either a linear or logarithmic transfer function. Alternatively, if the transfer function of the detection system is known, but is non-linear, a suitable set of correction factors can be developed and applied to correct the non-linear ranges of the transfer function. Local median values may be employed. If the difference between the local mean and local median exceeds approximately 2 dB, the distribution of the statistic shall be evaluated and an appropriate analysis performed.

6.8.2 Talk Out vs. Talk In Testing

Conformance testing need only be done in the Talk Out (outbound) direction. Reciprocity will apply and an offset correction value may be used to evaluate talk in (inbound) performance. If there is a large difference in height between the site transmit antenna and receive antenna, the assumption of reciprocity may not be valid. The additional expense and complexity of a talk in test may be justified in the following cases:

- Antenna distortions due to antenna support structure
- High ambient noise levels at site or in field
- Different Selectivity or Mode for Talk Out (down link) and Talk In (up link)
- Diversity
  - ♦ Macro (Voting)
  - ♦ Micro (On Site Receiver Combiner)
- Different Horizontal Antenna Patterns

6.8.3 Calibration of a CPC Evaluation Receiver

A CPC evaluation receiver should be calibrated to its antenna input port using a signal source whose absolute level accuracy is specified within ± 1.0 dB. Coaxial cable losses shall be calibrated out. The calibration signal source shall have been calibrated within the time interval recommended by its manufacturer, but in no event more than one year prior to calibrating the test receiver. Prior to calibrating the CPC evaluation receiver, the calibration signal source shall have been warmed up according to its manufacturer's recommendation for guaranteed amplitude accuracy, but in no event for less than 30 minutes.

When BER is the criterion, the CPC evaluation receiver should have attenuators added so that its reference sensitivity is obtained at its specified power level. This is necessary to prevent a very sensitive receiver from biasing the test results. When received power is being measured, it is unnecessary to derate a receiver to its simulated test reference sensitivity.

6.8.4 RSSI Mobile

Using a substitution method, the loss of the calibration coaxial cable should be measured and the receiver calibration table adjusted to represent the median signal strength required to produce RSSI indications over the dynamic range of the RSSI circuit. The maximum step size should be 1 dB from the RSSI threshold for 20 dB, then 2 dB size steps for 20 dB, and 5 dB steps thereafter. Local Mean Power shall be measured with a receiver calibrated at its antenna port. The use of a mean power value generally requires a detection system possessing a linear or logarithmic transfer function. Alternately, if the transfer function of the detection system is known but is non-linear, a suitable set of correction factors can be developed and applied to correct the non-linear ranges of the transfer function.

6.8.5 RSSI Fixed End

Using a substitution method, the loss of the calibration coaxial cable should be measured and the receiver calibration table adjusted to represent the median signal strength required to produce RSSI indications over the dynamic range of the RSSI circuit. The maximum step size should be 1 dB from the RSSI threshold for 20 dB, then 2 dB size steps for 20 dB, and 5 dB steps thereafter. Local Mean Power shall be measured with a receiver calibrated at its antenna port. The use of a mean power value generally requires a detection system possessing a linear or logarithmic transfer function. Alternatively, if the transfer function of the detection system is known, but is non-linear, a suitable set of correction factors can be developed and applied to correct the non-linear ranges of the transfer function.

6.8.5.1 Multicoupler Correction

When a receiver is fed by a receiver multicoupler or has a tower mounted preamplifier installed, a calibration curve should be created to compensate for the additional gain and amplified noise that will exist. This is a practical measure as injecting signals at the amplifier input can interrupt service for other receivers. A Noise Gain offset to calibrate the RSSI will apply, but the weak signal region will required a separate calibration.

The RSSI Noise offset will consist of the Surplus Gain, the overall gain between the first amplifier input and the subsequent losses prior to the input of the test base receiver, less the Effective Multicoupler Gain (EMG), which is the effective improvement in reference sensitivity between the input of the first amplifier stage and the reference sensitivity of the base receiver alone.

RSSI Noise Gain Offset = Surplus Gain - EMG [Eq. 39]

EMG = Reference sensitivity at first amplifier input - base reference sensitivity w/o amplifiers, but with amplifiers providing their noise contribution. This requires a directional coupler methodology for measuring the effect of the base receiver.

Referring to Figure 14:

a) Measure and record the test receiver static reference sensitivity through a calibrated directional coupler, C1, with its input terminated in 50 Ω S-1 to [redacted]

b) Repeat and record the measurement through directional coupler C1 with its input port connected to the amplifier chain, S-1 to B and S-2 to A, terminated in 50 Ω .

c) Measure and record the test receiver static reference sensitivity through the calibrated directional coupler C2 with its input terminated in 50 Ω, S-1 to B, S-2 to A. Record the insertion loss of the calibrated directional coupler C2.

d) Calculate the EMG, Step (a) power minus Step (c) power, both corrected for coupler insertion losses.

e) Calculate the Total Gain, Step (b) power minus Step (c) power, both corrected for coupler insertion losses.

f) Calculate the RSSI Noise Gain Offset. Step (b) power minus Step (a) power , both corrected for coupler insertion losses. This should also equal the difference calculated in steps (d) and (e).

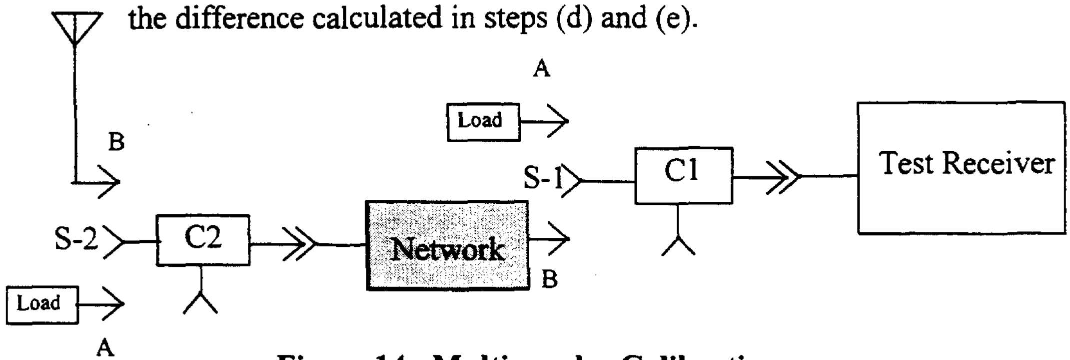

Figure 14. Multicoupler Calibration

g) Calibrate the RSSI by normalizing the input power level at C1 to that of a receiver that isn't connected to a multicoupler scheme. This would require that the "normalized" input power be Greater than the reference sensitivity by the RSSI Noise Gain Offset in dB.

h) For example, assume that the reference static sensitivity is -119 dBm, the Cs/N is 7 dB which infers that the noise floor of the receiver is -126 dBm. The corrected measurement a) would be -119 dBm. Corrected Measurement b) is -115.3 dBm and corrected measurement c) is -123.3 dBm. From this measurements, the EMG is (-119 -(-123.3)) = 4.3 dB. The Total Gain is (-115.3 - (-123.3)) = 8 dB. The RSSI Noise Gain Offset is (-115.3 -(-119)) = 3.7 dB. Thus the receiver requires a -115.3 dBm signal power to produce the same reference performance as a -123.3 dBm signal would at the input to the first amplifier. Thus by injecting the calibration signal at the input of the receiver at the RSSI Noise Gain Offset value, it is equivalent to injecting a signal at the input of the first amplifier which is EMG dB greater than the reference sensitivity of the receiver by itself, which isn't always practical when a system is in service.

6.9 Identifying Interference

Interfering carriers have the impact of affecting performance similar to an increase in noise. Since BER and RSSI can be measured, a reasonable calculation of interference can be made from evaluating these two related parameters.

BER can be mapped into $C_f/(I+N)$, e.g., a BER of 2% might, for example correspond to a ratio of 17 dB (50). RSSI is essentially C + I + N. When calibrated this might indicate that when a particular test yielded a measured 2% BER, the total power was for example -90 dBm (10^{-12} W). Thus the C and I + N components can be solved for. Measurements of idle channels can resolve the value of N to a reasonable value. Thus the C and I values can be solved for. High BER measurements at normal RSSI indications would represent increased I or N contributions. In the previous example, it would appear that if N is at -124 dBm, then there is an interferer at approximately -108 dBm.

7.0 Definitions and Abbreviations

There is a comprehensive Glossary of Terms, Acronyms, and Abbreviations listed in Appendix-A of TIA TSB102. In spite of its size, numerous unforeseen terms will have to be defined for the Compatibility aspects. Additional TIA/EIA references include; 603, Land Mobile FM or PM Communications Equipment Measurement and Performance Standards; TSB102.CAAA Digital C4FM/CQPSK Transceiver Measurement Methods; TSB102.CAAB, Digital C4FM/CQPSK Transceiver Performance Recommendations. ANSI/IEEE Std 100-1984. IEEE Standard Dictionary of Electrical and Electronic Terms will also be included as applicable. Items being specifically defined for the purpose of this document will be indicated as (New). All others will be referenced to their source as follows:

ANSI TIA/EIA-603	[T/E-603]
TIA TSB102, Appendix A	[102/A]
TIA TSB102.CAAA	[102.CAAA]
TIA TSB102.CAAB	[102.CAAB]
IEEE Standard Dictionary	[IEEE]
ITU-R [8A/XB]	[ITU-R]
New for this document	[New]

7.1 Definitions

ACCPR Adjacent Channel Coupled Power Ratio. The energy coupled into a victim receiver from an interfering carrier, relative to its average power on its assigned channel. The selectivity of the victims receiver and the Spectral Power Density of the interfering carrier interact to calculate this parameter.

ACIPR Adjacent Channel Interference Protection Ratio. See Adjacent Channel Rejection in TSB102.CAAA.

Adjacent Channel. The RF channel assigned adjacent to the licensed channel. The difference in frequency is determined by the channel bandwidth.

Adjacent Channel Coupled Power (ACCP). The energy from an adjacent channel transmitter that is intercepted by a victim receiver, relative to the power of the emitter.

Adjacent Channel Rejection [TSB102.CAAA]. The adjacent channel rejection is the ratio of the level of an unwanted input signal that causes the BER produced by a wanted signal 3 dB in excess of the reference sensitivity to be reduced to the standard BER, of the reference sensitivity. The analog adjacent channel rejection is a measure of the rejection of an unwanted signal that has an analog modulation. The digital adjacent channel rejection is a measure of rejection of an unwanted signal that has a digital modulation.

Cross analog to digital or digital to analog, require that the adjacent channel be modulated with its appropriate standard Interference Test Pattern modulation and that the test receiver use its reference sensitivity method.

Aegis [New]. Trademarked name for Ericsson trunked radio system.

"Area" Propagation Model. A model that does not predict power levels based upon the characteristics of path profiles.

Boltzmann's Constant (k). A value 1.3805x 10^{-23} J/K (Joules per Kelvin) At room temperature K = 290°.

C4FM [TSB102]. A 4-ary FM modulation technique that produces the same phase shift as a compatible CQPSK modulation technique. Consequently, either modulation may be received by the same receiver.

Co-Channel. Another licensee, potential interferer, on the same center frequency.

Confidence Interval. A statistical term where a confidence level is stated for the probability of the true value of something being within a given range which is the interval.

Confidence Level. The degree of confidence used in conjunction with a confidence interval to state the probability that the true value lies within that interval.

"Contour" Reliability. The probability of obtaining the CPC at the boundary of the Service Area. It is essentially the minimum allowable design probability for a specified performance.

CQPSK [TSB102]. The acronym for Quadrature Phase Shift Keyed (QPSK) AM transmitter which uses QPSK-c modulation to work with a compatible frequency discriminator detection receiver. See also C4FM.

Channel Performance Criterion [New]. The BER and vehicular Doppler fading rate required to deliver a specific MOS for the specific modulation. The CPC should be in the form of C_f/N, $C_f/(I+N)$ @ X Hz Doppler.

DAQ [New]. The acronym for Delivered Audio Quality, a reference similar to Circuit Merit with additional definitions for digitized voice and a static SINAD equivalent intelligibility when subjected to multipath fading.

DIMRS [ITU-R]. The acronym for Digital Integrated Mobile Radio Service, representing a trunked digital radio system using multi-subcarrier digital QAM modulation.

Dipole. A half wave dipole is the standard reference for fixed station antennas. The gain is relative to a half wave dipole and is in dBd.

Effective Multicoupler Gain (EMG). The effective improvement in reference sensitivity between the input of the first amplifier stage and the reference sensitivity of the base receiver alone.

Equivalent Noise Bandwidth (ENBW). The noise bandwidth of a receiver. As it is very close to the ± 3 dB bandwidth, that value can be substituted if the exact effective bandwidth is unknown.

Faded Reference Sensitivity [TSB102.CAAA] The faded reference sensitivity is the level of receiver input signal at a specified frequency with specified modulation which, when applied through a faded channel simulator, will result in the standard BER at the receiver detector.

FFSR. Feed Forward Signal Regeneration: An adaptive equalization technique developed by McGeehan and Bateman to correct for amplitude and phase perturbations in a received signal by means of a reciprocal fading generator. FFSR is used in conjunction with TTIB.

FFSR/TTIB LM. A linear modulation implementation employing McGeehan and Bateman's channel linearization and equalization techniques.

Height Above Average Terrain (HAAT). The height of the radiating antenna above the average terrain which is determined by averaging equally spaced data points along radials from the site or the tile equivalents. Only that portion of the radial between 3 and 16 km should be averaged.

IMBE [TSB102]. The acronym for Improved Multi Band Excitation, the standard vocoder per TSB102.BAAA. "A voice coding technique based on Sinusoidal Transform Coding (analog to digital voice conversion)."

Inferred Noise Floor. The noise floor of a receiver calculated when the Reference Sensitivity is reduced by the static C_s/N required to obtain the Reference Sensitivity.

Interference Limited. The case where the CPC is dominated by the Interference component of C/(I+N).

Isotropic. An isotropic radiator is an idealized model where its energy is uniformly distributed over a sphere. Microwave point to point antennas are normally referenced to dBi.

Linear Modulation. Phase linear and amplitude linear frequency translation of baseband to passband and radio frequency

Lee's Method. The method of determining how many subsamples of signal power should be taken over a given number of wavelengths for a specified confidence that the overall sample is representative of the actual signal within a given number of decibels.

Local Mean. The mean power level measured when a specific number of samples are taken over a specified number of wavelengths. Except at frequencies less than 300 MHz, the recommended values are 50 samples and 40λ.

Local Median. The median value of measured values obtained while following Lee's method to measure the Local Mean.

Location Variability. The standard deviation of measured power levels that exist due to the variations in the local environment such as terrain and environmental clutter density variations.

Macro Diversity. Commonly used as "voting", where sites separated by large distances are compared and the best is "voted" to be the one selected for further use by the system.

Mean Opinion Score. The opinion of a grading body that has evaluated test scripts under varying channel conditions and given them a MOS.

Measurement Error. The variability of measurements due to the measuring equipment's accuracy and stability.

Micro Diversity. Receivers at the same site are selected among or combined to enhance the overall quality of signal used by the system after this process.

Noise Gain Offset (NGO). The difference between the overall gain preceding the base receiver (Surplus Gain) and the improvement in reference sensitivity (EMG).

Noise Limited. The case where the CPC is dominated by the Noise component of C/(I+N).

Normalized Power-Density Spectrum. The power-density in each frequency bin relative to the total power of the emission.

Number of Test Grids. The number of uniformly distributed but randomly selected test locations used to measure the CPC. It is calculated using the Estimate of Proportions formula and the specified Area Reliability, Confidence Interval and Sampling Error.

$\pi/4$ DQPSK [TSB102]. The acronym for "Differential Quadrature Phase Shift Keying", "quadrature" indicates that the phase shift of the modulation is a multiple of 90 degrees. Differential indicates that consecutive symbols are phase shifted 45 degrees ($\pi/4$) from each other.

Point to Point Model. A model that uses path profile data to predict path loss between points.

Power-Density Spectrum (PDS) [IEEE]. A plot of power density per unit frequency as function of frequency.

Power Spectral Density (PSD). The energy in dB relative to peak or rms power per Hertz.

Protected Service Area (PSA) [New]. That portion of a licensee's service area or zone that is to be afforded protection to a given reliability level from co-channel and adjacent channel interference and is based on predetermined service contours.

QPSK-c. The acronym for the Quadrature Phase Shift Keyed family of compatible modulations, which includes CQPSK and C4FM.

Reference Sensitivity [TSB102.CAAA]. The reference sensitivity is the level of receiver input signal at a specified frequency with specified modulation which will result in the standard BER at the receiver detector. [TIA/EIA-603] The reference sensitivity is the level of receiver input signal at a specified frequency with specified modulation which will result in the standard SINAD at the output of the receiver.

Sampling Error. The error from not being able to measure the true value by sampling the entire population.

Service Area. The boundary of the geographic area of concern for a user. Usually a political boundary such as a city limits, county limit or similar definition for the users business. Can be defined relative to site coordinates or an irregular polygon where points are defined by latitude and longitude.

Signal-to-Noise Ratio (SINAD). [E/T-603] The Signal-to-Noise Ratio (SINAD) is:

$$SINAD(dB) = 20\log_{10}\left[\frac{Signal + Noise + Distortion}{Noise + Distortion}\right]$$

where: Signal = Wanted audio frequency signal voltage due to standard test modulation. Noise = Noise voltage with standard test modulation. Distortion = Distortion voltage with standard test modulation.

Spectral Power Density (SPD) [IEEE]. The power density per unit bandwidth.

Standard BER [102.CAAA]. Bit Error Rate (BER) is the percentage of the received bit errors to the total number of bits transmitted. The value of the standard bit error rate (BER) is 5%.

Standard Deviate Unit (SDU). Also "Standard Normal Deviate." That upper limit of a truncated normal (Gaussian) curve with zero mean and infinite lower limit which will produce a given area under the curve (e.g., Z = +1.645 for Area =0.95).

Standard Interference Test Pattern. [TSB102.CAAA] The standard digital transmitter test pattern is a continuously repeating 511 binary pseudo random noise sequence based on ITU-T V.52. Refer to ANSI TIA/EIA-603-196, 2.1.7 for the analog version. The standard analog digital transmitter test pattern is two tones, one at 650 Hz at a deviation of 50% of the maximum permissible frequency deviation, and another at 2200 Hz at a deviation of 50% of the maximum permissible frequency deviation.

Standard SINAD [ANSI EIA/TIA-603] The value of the standard signal-to-noise ratio is 12 dB. The standard signal-to-noise ratio (SINAD) allows comparison between different equipment when the standard test modulation is used.

Subsample. A single measured value. Part of a Test Sample.

Surplus Gain. The sum of all gains and losses from the input of the first amplified stage until the input to the base receiver.

Talk Out. From the fixed equipment outward to the "mobile" units. Also referred to as a forward link or down link.

Talk In. From the "mobile equipment" inbound to the fixed equipment. Also referred to as a reverse link or up link.

TTIB. Transparent Tone In Band: A technique developed by McGeehan and Bateman to provide an unambiguous frequency, phase and amplitude reference for use in linear modulation systems. TTIB is used in conjunction with FFSR.

Test Grid. The overall network of tiles where random samples of the CPC are taken.

Test Sample. A group of subsamples which are measured at a Test Tile.

Test Tile. The location where the random sample of CPC will be taken.

Tile Reliability [New]. The number of tiles which contain a margin equal to or greater than the Tile Reliability Margin, divided by the total number of tiles in the service area, expressed as a percentage. This is a direct way to calculate the CPC Area Reliability.

Tile Reliability Margin [New]. The margin, in dB, provided to create a minimum acceptable probability of achieving the required CPC in a tile. This is not to be confused with the CPC Area Reliability.

Voting. The process of comparing received signals and selecting the instantaneous best value and incorporating it into the system.

7.2 Abbreviations

4CPM	4-ary (Four Level) Continuous Phase Modulation
APCO	Association of Public Safety Communications Officials International, Inc.
ACCPR	Adjacent Channel Coupled Power Ratio
ACIPR	Adjacent Channel Interference Protection Ratio
ACPR	Adjacent Channel Protection Ratio
ANSI	American National Standards Institute
ATP	Acceptance Test Plan
BER	Bit Error Rate
C4FM	4-ary FM QPSK-C; Compatible Four Level Frequency Modulation
CAE	Counter Address Encoder
CCIPR	Co Channel Interference Protection Ratio (capture)
CCIR	International Radio Consultative Committee (Now ITU-R)
CFB	Cypher Feedback
CPC	Channel Performance Criterion
$C_f/(I+N)$	Faded Carrier to Interference plus Noise ratio
C_f/N	Faded Carrier to Noise ratio
C/I	Carrier to Interference signal ratio
CQPSK	AM QPSK-C; Compatible Quadrature Phase Shift Keying
C_s/N	Static Carrier to Noise ratio
CTG	Composite Theme Grids
CVSD	Continuously-Variable Slope Delta modulation

DAQ	Delivered Audio Quality
dBd	Decibels relative to a half wave dipole
dBqw	Decibels relative to a quarter wave antenna
dBi	Decibels relative to an isotropic radiator
dBμ	Decibels referenced to 1 microvolt per meter (1 μV/m)
DEM	Digital Elevation Model
DIMRS	Digital Integrated Mobile Radio System
DMA	Defense Mapping Agency
DQPSK	Differential Quadrature Phase-Shift Keying
DVP	Digital Voice Protection
$\frac{E_b}{N_0}$	Energy per bit per Hertz
EDACS®	Enhanced Digital Access Communication System
EMG	Effective Multicoupler Gain
ENBW	Equivalent Noise Bandwidth
erf	Error Function
erfc	Complementary Error Function
FDMA	Frequency Division Multiple Access
FFSR	Feed Forward Signal Regeneration
F-TDMA	Frequency, Time Division Multiple Access
HAAT	Height Above Average Terrain
iDEN™	Integrated Digital Enhanced Network
IMBE	Improved Multi Band Excitation
IMR	Intermodulation Rejection
ITU-R	International Telecommunication Union - Radiocommunication Sector
ITU-T	International Telecommunication Union - Telecommunication Sector
LM	Linear Modulation
LULC	Land Usage/Land Cover
MOS	Mean Opinion Score
NASTD	"National Association of State Telecommunications Directors"
NF	Noise Factor
NF_{db}	Noise Figure
NGDC	National Geophysical Data Center (under the Department of Commerce, located in Boulder, Colorado
NPSPAC	National Public Safety Planning Advisory Committee
OHD	Okumura/Hata/Davidson model
PEC	Perfect Electrical Conductor
PSA	Protected Service Area
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase-Shift Keying
QPSK-c	Quadrature Phase-Shift Keying - Compatible
QQAM	Quad Quadrature Amplitude Modulation (see TSB102)

RSSI	Receiver Signal Strength Indication
RZ SSB	Real Zero Single Sideband
SPD	Spectral Power Density
TBD	To Be Determined
TDMA	Time Division Multiple Access
TIREM	Terrain Integrated Rough Earth Model
TTIB	Transparent Tone In-Band
USGS	United States Department of the Interior, Geological Survey
Z	Standard Deviate Unit

8.0 References

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Appendix-A. Tables

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Table 1. Delivered Audio Quality

DAQ Delivered Audio Quality	Subjective Performance Description	SINAD equivalent intelligibility[1,2]
1	Unusable, Speech present but unreadable	<8 dB
2	Understandable with considerable effort. Frequent repetition due to Noise/Distortion	12 ± 4 dB
3	Speech understandable with slight effort. Occasional repetition required due to Noise/Distortion	17 ± 5 dB
3.4	Speech understandable without repetition. Some Noise/Distortion	20 ± 5 dB
4	Speech easily understood. Occasional Noise/Distortion	25 ± 5 dB
4.5	Speech easily understood. Infrequent Noise/Distortion	30 ± 5 dB
5	Speech easily understood.	>33 dB

[1] CPC is set to the midpoint of the range.
[2] SINAD values are ***NOT*** to be used for system performance assessment.

Table 2. Antenna Reference Conversions

		Antenna Reference	
Specific Antenna	**Isotropic**	**$\lambda/2$ halfwave dipole**	**$\lambda/4$ quarterwave**
Isotropic	0 dBi	-2.15 dBd	-1.15 $dB_{1/4}$
$\lambda/4$ quarterwave	1.15 dBi	-1.0 dBd	0 $dB_{1/4}$
$\lambda/2$ halfwave dipole	2.15 dBi	0 dBd	1 $dB_{1/4}$

Table 3. IF Filter Specifications for Prototype Receivers

Modulation Type	ENBW (kHz)	IF Filter Simulation	Bandwidth (kHz)[1]
Analog FM (25 kHz) ±5 kHz	12.6	*	±7.5
Analog FM (25 kHz) ±4 kHz NPSPAC	10.1	*	±6.0
Analog FM (12.5 kHz) ±2.5 kHz	7.8	*	±4.6
C4FM	5.7	*	±3.4
CQPSK	5.7	12-pole Inverse Cheby†	±3.65
CVSD (25 kHz) ±4 kHz	12.6	*	±7.5
CVSD (25 kHz) ±3 kHz NPSPAC	10.1	*	±6.0
π/4 DQPSK (IMBE) TDMA (12.5 kHz)	9.5	*	±5.6
EDACS® (IMBE) (25 kHz)	9.8	*	±5.8
EDACS® (IMBE) (12.5 kHz)	9.1	*	±5.4
DIMRS	16.0	RRC, α=0.2	±8.75
TTIB FFSR	3.9	8-pole Inverse Cheby†	±2.5
RZ SSB	3.9	8-pole Inverse Cheby†	±2.5

[1] Filter Parameters for use with the formulas.

* Cascade of three 4-pole Butterworth stages, each 4-pole stage having a 3 dB bandwidth as given in the "Bandwidth" column.

† $\varepsilon = 0.0003$

RRC = Root Raised Cosine filter

Table 4. Filter Formulas

Butterworth Filter Equation
$$\text{Attenuation} = C \bullet 10 \bullet \log_{10}\left[1+\left(\frac{\Delta f}{\Delta f_0}\right)^{2n}\right]$$
C = The number of cascades Δf = The frequency offset from the IF center frequency Δf_0 = The frequency offset of the corner frequency n = Number of poles

Inverse-Chebyshev Equation
$$\text{Response in dB} = 10 \bullet \log_{10}\left[\frac{\varepsilon^2 \bullet \left[C_n\left(\frac{\Delta f_0}{\Delta f}\right)\right]^2}{1+\left\{\varepsilon^2 \bullet \left[C_n\left(\frac{\Delta f_0}{\Delta f}\right)\right]^2\right\}}\right]$$
$C_n(x) = \cosh[n * \cosh^{-1}(x)]$ for $x > 1$ $C_n(x) = \cos[n * \cos^{-1}(x)]$ for $x \le 1$ Δf = The frequency offset from the IF center frequency Δf_0 = The frequency offset of the corner frequency ε = Minimum stop-band attenuation n = Number of poles

Root Raised Cosine Equations
$$M(f) = 0dB \; ; \; \frac{f}{f_0} \le 1-\alpha$$ $$M(f) = 10\log_{10}\left\{\cos\left[\frac{\pi\left(\frac{f}{f_0}-1+\alpha\right)}{4\alpha}\right]^2\right\}; \; 1-\alpha < \frac{f}{f_0} \le 1+\alpha$$ $$M(f) = -\infty \; ; \; 1+\alpha < \frac{f}{f_0}$$
f_0 = symbol frequency/2, i.e., for 9.6 kb/s with four levels the symbol frequency is 4.8 kS/s, therefore f_0 is 2,400.

Table 5. *Projected* CPC Requirements for Different DAQs

Modulation Type, (channel spacing)	Static[1] $ref/\frac{C_s}{N}$	DAQ-3.0[2] $BER\%/\frac{C_f}{(I+N)}$	DAQ-3.4[3] $BER\%/\frac{C_f}{(I+N)}$	DAQ-4.0[4] $BER\%/\frac{C_f}{(I+N)}$
Analog FM ± 5kHz (25 kHz)	12 dBS/4dB	na/17 dB	na/20 dB	na/27 dB
Analog FM ± 4kHz (25 kHz)[5]	12 dBS/5dB	na/19 dB	na/22 dB	na/29 dB
Analog FM ± 2.5kHz (12.5 kHz)	12 dBS/7dB	na/23 dB	na/26 dB	na/33 dB
C4FM (IMBE) (12.5 kHz)[6]	5%/5.4 dB	2.6%/15.2 dB	2.0%/16.2 dB	1.0%/20.0 dB
C4FM (IMBE) (12.5 kHz)[7]	5%/7.6 dB	2.6%/16.5 dB	2.0%/17.7 dB	1.0%/21.2 dB
CQPSK (IMBE) (12.5 kHz)[6]	5%/5.4 dB	2.6%/15.2 dB	2.0%/16.2 dB	1.0%/20.0 dB
CQPSK (IMBE) (12.5 kHz)[7]	5%/7.6 dB	2.6%/16.5 dB	2.0%/17.7 dB	1.0%/21.2 dB
CQPSK (IMBE) (6.25 kHz)	5%/7.6 dB	2.6%/16.5 dB	2.0%/17.7 dB	1.0%/21.2 dB
CVSD "XL" CAE (25 kHz)	8.5%/4 dB	5%/12.0 dB	3%/16.5 dB	1%/20.5 dB
CVSD "XL" CAE (NPSPAC)[8]	8.5%/4 dB	5%/14.0 dB	3%/18.5 dB	1%/22.5 dB
C4FM (VSELP)* (12.5 kHz)[6]	5%/5.4 dB	1.8%/17.4 dB	TBD	0.85%/21.6 dB
C4FM (VSELP)* (12.5 kHz)[7]	5%/7.6 dB	1.8%/17.4 dB	TBD	0.85%/21.6 dB
EDACS® Aegis (25 kHz)	TBD	TBD	TBD	TBD
EDACS® Aegis (12.5 kHz)	TBD	TBD	TBD	TBD
π/4 DQPSK (IMBE) TDMA (12.5 kHz)	5%/6.9 dB	2.6%/15.2 dB	2.0%/16.4 dB	1.0%/19.5 dB
EDACS® (IMBE) (25 kHz)	5%/5.3 dB	2.6%/14.7 dB	2.0%/15.7 dB	1.0%/19.2 dB
EDACS® (IMBE) (12.5 kHz)	5%/7.3 dB	2.6%/16.7 dB	2.0%/17.7 dB	1.0%/21.2 dB
DIMRS (25 kHz)	5%/12.5 dB	2.0 %/22 dB	TBD	1%/25 dB
TTIB/FFSR Analog LM (5 kHz)	TBD	TBD	TBD	TBD
TTIB/FFSR 16 QAM LM (5 kHz)	TBD	TBD	TBD	TBD
TTIB/FFSR 128 QAM LM (5 kHz)	TBD	TBD	TBD	TBD
RZ-SSB Analog LM (5 kHz)	TBD	TBD	TBD	TBD
RZ-SSB 16 QAM LM (5 kHz)	TBD	TBD	TBD	TBD

Note: These values were obtained from the manufacturers and should be verified with the manufacturer prior to usage.
* These VSELP values represent worst case, low speed.

[1] Static is the reference sensitivity of a wireless detection sub-system (receiver) and is comparable to 12 dB SINAD in an analog system
[2] DAQ-2.0 (not shown) is comparable to 12 dB SINAD equivalent intelligibility,
DAQ-3.0 is comparable to 17 dB SINAD equivalent intelligibility
[3] DAQ-3.4 is comparable to 20 dB SINAD equivalent intelligibility, used for minimum CCP for some public safety entities.
[4] DAQ-4.0 is comparable to 25 dB SINAD equivalent intelligibility
[5] This is a NPSPAC configuration, 25 kHz channel bandwidths, but 12.5 kHz channel spacing. 20 dB ACIPR receiver assumed
[6] A wide IF bandwidth assumed as part of a migration process
[7] A narrow IF bandwidth is assumed after migration is completed.
[8] Reduced deviation for NPSPAC requirement.

Table 6. Protected Service Areas

Candidate Channel #1 Frequency XXX.YYYY		PSAs Associated with Candidate Channel #1						Candidate Channel #1	
Test AAR%	Order	Co-1 AAR%	Order	Co-2 AAR%	Order	Adj-1 AAR%	Order	Sum Orders	Rank
95	1	90	2	90	3	92	1	7	1
94	2	85	4	91	2	90	2	10	3
93	3	92	1	92	1	87	3	8	2
92	4	87	3	88	4	n/a		11	4

Candidate Channel #2	PSAs Associated with Candidate Channel #2	Candidate Channel #2
Channel #2 Results	Channel #2 Results	Channel #2 Results

Table 7. Test Signals

Modulation Type	Modulation Test Signal
Analog FM (± 5 kHz)	650 Hz tone & 2.2 kHz tone per Section 6.6.6.2
Analog FM, NPSPAC (± 4 kHz)	650 Hz tone & 2.2 kHz tone per Section 6.6.6.2
Analog FM (± 2.5 kHz)	650 Hz tone & 2.2 kHz tone per Section 6.6.6.2
C4FM (12.5 kHz)	ITU-T V.52 per TSB102.CAAA
QPSK-c (6.25 kHz)	ITU-T V.52 per TSB102.CAAA
CVSD - Normal (± 4 kHz)	12.0 kb/s binary ITU-T V.52 sequence
CVSD - NPSPAC (± 3 kHz)	12.0 kb/s binary ITU-T V.52 sequence
EDACS® Aegis (25 kHz)	9.6 kb/s binary ITU-T V.52 sequence
EDACS® Aegis (12.5 kHz)	9.6 kb/s binary ITU-T V.52 sequence
π/4 DQPSK (IMBE) TDMA (12.5 kHz)	18 kb/s 4-level ITU-T V.52 sequence
EDACS® (IMBE) (25 kHz)	9.6 kb/s binary ITU-T V.52 sequence
EDACS® (IMBE) (12.5 kHz)	9.6 kb/s binary ITU-T V.52 sequence
DIMRS (25 kHz)	TBD
TTIB/FFSR Analog LM (5 kHz)	TBD
TTIB/FFSR 16 QAM LM (5 kHz)	TBD
TTIB/FFSR 128 QAM LM (5 kHz)	TBD
RZ SSB Analog LM (5 kHz)	400 Hz tone & 1.0 kHz tone @ equal levels
RZ SSB 16 QAM LM (5 kHz)	TBD